

# SENSOR ARRANGEMENT HAVING AN AIR INFLOW PATTERN FOR PREVENTING DIRECT DEBRIS IMPACT

## RELATED APPLICATION

[0001] This application claims priority under 35 U.S.C. § 119(e) of  
5 U.S. Provisional Application 60/514,688 filed on October 28, 2003, the  
entire contents of which are herein incorporated by reference.

## FIELD OF THE INVENTION

[0002] This invention relates to temperature sensors, and more  
particularly to a temperature sensor arrangement in which the sensor  
10 outer casing has a pattern of air flow passages arranged to allow air  
inflow to a temperature sensing element while preventing airborne debris  
from directly impacting the temperature sensing element.

## BACKGROUND OF THE INVENTION

[0003] A known temperature sensor arrangement measures the  
15 temperature of air flowing in a passageway and includes a generally  
cylindrical housing having a cavity in which a sensing element is  
positioned along a center line. The outer casing of one known sensor  
arrangement includes slots carved out on the center line to allow air  
inflow to the sensing element. One implementation for such a known  
20 temperature sensing arrangement is in an aircraft bleed air system, which  
carries air from a gas turbine engine for pressurization, compartment  
temperature control, and wing anti-icing systems. Although the slot  
arrangement of this known temperature sensor device protects the  
sensing element from large debris, the inventors of this application have  
25 found that smaller debris (e.g., sand) passing through the gas turbine  
engine may cause damage to the sensing element due to the debris  
impacting the sensor element. Design constraints typically preclude  
moving the sensor to a safer location, clocking the sensor, or changing  
the sensor time constant to the point that a pneumatic system controller  
30 change would be required.

[0004] In one aspect, the present invention addresses drawbacks of the above-described temperature sensor design by incorporating a flow passage pattern that substantially reduces or eliminate damage due to debris impacting the sensor, thereby improving reliability and extending operation life of the temperature sensor.

#### SUMMARY OF THE INVENTION

[0005] The present invention, in one aspect, is a temperature sensor arrangement designed to allow air inflow to a temperature sensing element through a series of air flow passages while preventing/mitigating the effect of debris impacting the sensing element. In one embodiment, the present invention is temperature sensor arrangement comprising: a sensor cavity, a temperature sensing element being positioned along a center line of the sensor cavity and generating a signal indicating temperature of air flowing thereto; and a generally cylindrical outer casing surrounding the sensor cavity, the outer casing including a pattern of flow passages for allowing air flow to the temperature sensing element in the sensor cavity, the flow passages being angled such that there is no direct line of air flow from an exterior of the outer casing to the sensing element.

[0006] In an alternative embodiment, the present invention is a temperature sensor arrangement comprising: a sensor cavity, a temperature sensing element being positioned along a center line of the sensor cavity and generating a signal indicating temperature of air flowing thereto; and a generally cylindrical outer casing surrounding the sensor cavity, the outer casing including a pattern of flow passages for allowing air flow to the temperature sensing element in the sensor cavity, the flow passages being offset relative to a center line of the housing cavity such that there is no direct line of air flow from an exterior of said outer casing to the sensing element.

### BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Additional aspects and advantages of the present invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

5 [0008] FIG. 1A is an isometric and cross-sectional view of a temperature sensor arrangement according to a first embodiment of the present invention;

[0009] FIG. 1B is a side view of the temperature sensor arrangement according to the first embodiment of the present invention;

10 [0010] FIG. 1C is a front view of the temperature sensor arrangement according to the first embodiment of the present invention;

[0011] FIG. 1D is a rear view of the temperature sensor arrangement according to the first embodiment of the present invention;

15 [0012] FIG. 2 is an additional isometric view of a temperature sensor arrangement in accordance with the first embodiment of the present invention;

[0013] FIG. 3A is a side view of a temperature sensor arrangement according to a second embodiment of the present invention; and

20 [0014] FIG. 3B is a cross-sectional view of the temperature sensor arrangement according to the second embodiment of the present invention.

### DESCRIPTION OF THE INVENTION

[0015] In one aspect, the present invention is a temperature sensor arrangement designed to allow air inflow to a temperature sensing  
25 element through a series of passages in an outer casing while preventing/mitigating the effect of debris impacting the sensor. Additional aspects of the present invention will become apparent from the following description, with reference to the appended figures.

[0016] FIGs. 1A-1D illustrate a temperature sensor arrangement  
30 according to a first embodiment of the present invention. According to the first embodiment, the temperature sensor arrangement 100 includes a

generally cylindrical outer casing 105 with a pattern of openings (holes in this embodiment) 110 for allowing air inflow to a temperature sensing element positioned along a center line 140 in a cavity 150.

5 [0017] The temperature sensor arrangement 100 of the first embodiment may be implemented for use in an air duct so as to be positioned with the outer casing generally perpendicular to the air flow. In this way, the pattern of holes 110 allows air flow to the sensing element, which is positioned on the center line 140.

10 [0018] FIG. 1A is an isometric and cross-sectional view of the temperature sensor arrangement 100 according to the first embodiment. FIG. 1A illustrates a cross-section along line A-A (FIG. 1B). In the first embodiment, the holes 110 are angled to prevent airborne debris from directly impacting the temperature sensing element. In other words, there is no direct "line of sight" through the angled holes to the sensing element  
15 so that debris entering a hole 110 will impact at least one surface prior to entering the housing cavity 150, thus dissipating kinetic energy of the debris particles. The specific angle for the holes 110 may vary, depending for example on the thickness of the casing 105. In one implementation, the holes 110 may be equally spaced and drilled on a 45° angle. As  
20 shown in the isometric view of FIG. 1A and the front view of FIG. 1C, the temperature sensing arrangement 100 according to the first embodiment also includes a plurality of holes 120 in the front face to allow debris to exit the housing cavity 150. The rear surface of the temperature sensor arrangement 100 may include standard electrical connections 175 to  
25 output temperature measurements, such as shown in the rear view of FIG. 1D.

[0019] FIG. 2 is an additional isometric view of a temperature sensor arrangement 200 consistent with the first embodiment of the present invention, including a generally cylindrical outer casing 205, a pattern of  
30 angled air inflow holes 210 and front-face holes 220 for allowing debris to exit the housing cavity.

[0020] FIGs. 3A-3B illustrate a temperature sensor arrangement 300 according to a second embodiment of the present invention. As shown in FIG. 3A, the temperature sensor arrangement 300 of the second embodiment includes a generally cylindrical outer casing 305 designed to allow air inflow through a series of holes 310 that are generally perpendicular to the sensing element 330 centered in a housing cavity (e.g., same as the cavity 150 in FIG. 1A), the holes 310 being offset from the center line 340 of the probe by a distance greater than the diameter of the sensing element 330. With this arrangement, direct flow impingement on the sensing element 330 is minimal or non-existent, depending on the sensor orientation. FIG. 3B illustrates a cross-sectional view, along cross section 3B-3B shown in FIG. 3A, showing the casing material as cross-hatched. As shown in FIG. 3B, there is no direct line of sight through the holes 310 to the sensing element 330, such that direct impact of airborne debris to the temperature sensing element is minimized. The temperature sensor arrangement 300 of the second embodiment may have a rear and front configuration like that shown in FIGs. 1D and 1C, respectively. Advantages of aspects of the above-described embodiments are described below.

[0021] The above-described embodiments allow the temperature sensor to more reliably operate in an environment that contains debris, by minimizing or eliminating impact damage on the temperature sensing element of the sensor. Design variations on these concepts include flow passage hole diameters and sensor casing wall thickness.

[0022] The sensor outer casing is preferably a metallic part. A preferred material is 347 Stainless Steel, for consistency with the other sub-components of the temperature sensor. Other grades of stainless steel and other metals may also be used, based on their suitability for operation in a high temperature (e.g., up to 1200°F) and high stress environment, and compatibility with the other components of the sensor.

The sensor outer casing may be manufactured through a machining process or as a casting.

[0023] In one specific implementation, the above-described embodiments are designed to improve reliability and extend operational  
5 life of the temperature sensor by protecting the temperature sensing element from debris damage in high temperature bleed air environments such as can be found in aircraft implementations. The invention may be designed to be a sub-component of a temperature sensor system, and may be applied to the temperature sensor for use in various applications,  
10 including (but not limited to) pneumatic bleed systems of commercial aircraft.

[0024] The above-described embodiments do not require unique or specific orientation of the sensor within a flow stream (a.k.a., "clocking") in order to function. These embodiments are designed to protrude into the  
15 flow stream through a hole in the side of an existing duct, such as a typical sensor mounting boss in an aircraft ducting. This allows it to be easily retrofitted into existing temperature sensor installations. In other words, custom designed duct installation is not required.

[0025] The housing is designed to absorb energy of solid matter  
20 particles as well as to deflect them away from the sensor probe, while maintaining sufficient airflow past the center probe so as to provide a response time comparable to a conventionally shielded or unshielded temperature sensor. Even if solid matter particles eventually come in contact with the sensing element, the particles lack sufficient energy to  
25 damage the sensing element. The present invention allows the hard particles to enter the housing in a state that does not damage the sensing element. Provision is made to evacuate the particles in question.

[0026] Although the temperature sensor arrangement according to aspects of the present invention may be installed in a bleed air system of  
30 an aircraft, other implementations of the temperature sensor arrangement are possible such as:

Temperature sensing on aircraft systems where ice impingement is a risk (i.e. downstream of an air conditioning pack);

Ram inlet temperature sensing on aircraft;

Air intakes on vehicles such as cars, tanks, and recreational  
5 vehicles.